Acknowledgements

These course notes were developed for the Fall 2008 offering of ECE 486: Control Systems. Material is covered in roughly the same order as in the textbook Feedback Control of Dynamic Systems (5th edition) by Franklin, Powell and Emami-Naeini. Parts of the course notes are based on lecture notes by Professor Daniel Liberzon, Professor Sean Meyn, and Professor Mark Spong (all from the University of Illinois). Much thanks to the students of ECE 486 for finding typos and errors in the course notes and material.
What is a System?
For the purposes of this course, a system is an abstract object that accepts inputs and produces outputs in response. Systems will also be referred to as plants or processes.

Example. Circuit, DC Motor, Economic System

What is Control?
The field of control systems deals with applying/choosing the inputs to a given system to achieve a desired output.

Key concept: Feedback Control
The input to the system depends in some way upon the output of the system. This is also called a closed loop system.

Example. Basic operation of a car cruise control system:

- Sensors (speedometers) in the car measure the current speed.
- The controller in the car uses these measurements to produce control signals (corresponding to the throttle angle).
- The control signals affect the speed of the car via actuators (i.e., the engine).

Basic block diagram of a feedback control system:
Other examples of feedback control systems:

- Aerospace
- Phase Lock Loops (PLLs)
- Computer disk drives
- Manufacturing systems
- Economic systems (Fed chooses interest rates based on current inflation, unemployment, growth, etc.)
- Ecological systems (predator/prey populations, global climate, etc.)
- Biological systems (the human body)

**Another example: Inverted Pendulum.** Suppose we try to balance a stick vertically in the palm of our hand. The sensor, controller and actuator in this example are our eyes, our brain, and our hand, respectively. This is an example of a feedback control system. Now what happens if we try to balance the stick with our eyes closed? The stick inevitably falls. This illustrates another type of control, known as feedforward control, where the input to the system does not depend on the output. As this example illustrates, feedforward control is not robust to disturbances – if the stick is not perfectly balanced to start, or if our hand moves very slightly, the stick will fall. We will see more advantages of feedback control vs. feedforward control later in the course.

*Aside:* Inverted pendulums appear in many practical applications such as construction equipment, rockets, Segways, etc.

**What is covered in this course?**

Control is prevalent everywhere, but not always obviously so (it is a “hidden technology”). Rather than attempting to discuss each specific application, this course will deal with the underlying mathematical theory, analysis, and design of control systems. In this sense, it will be more mathematical than other engineering courses, but will be different from other math courses in that it will pull together various branches of mathematics for a particular purpose (i.e., to design systems that behave in desired ways).

The trajectory of the course will be as follows.

- **Modeling:** Before we can control a system and make it behave in a desired manner, we need to represent the input-output behavior of the system in a form that is suitable for mathematical analysis.

- **Analysis:** Once we understand how to model systems, we need to have a basic understanding of what the model tells us about the system’s response to input signals. We will also need to formulate how exactly we want the output to get to its desired value (e.g., how quickly should it get there, do we care what the output does on the way there, can we be sure that the output will get there, etc.)

- **Design:** Finally, once we have analyzed the mathematical model of the system, we will study ways to design controllers to supply appropriate control (input) signals to the system so that the output behaves as we want it to.